



Available online
wjbr.interscholar.org

World Journal of Biological Research
Revue Mondiale de la Recherche Biologique

World Journal of Biological Research **002**: 1

MICROBIAL QUALITIES OF POTASSIUM SORBATE ON TREATED SMOKED TILAPIA (*Oreochromis niloticus*)

***Omojowo, F. S., Olorok, J.O. and Ihuahi, J.A.**

Fisheries Technology Division, National Institute for Freshwater Fisheries Research (NIFFR), P. M. B. 6006, New-Bussa, Niger-state, Nigeria.

Accepted 23 March 2009 / published June 2009

Summary

This study was carried out to assess microbial quality of potassium sorbate on Tilapia (*Oreochromis niloticus*) treated with varying concentration (1-5%) before smoking looking at its effects on the microbial load during 8-week storage at room temperature. The non-treated tilapia served as control and showed diverse and high microbial load while the treated smoked samples were negative for *E. coli* and *Streptococcus sp.* and recorded low TVC, coliform, staphylococcus and fungi count maintaining that low count till the end of the 8th week storage. Among the treatments, 3-5% proved very good. However, 3% treatment proved to be a better concentration since it was organoleptically acceptable and also reduced the *Staphylococcus count* to 0 even till the end of the 8th week storage.

Key words: Potassium sorbate, smoked tilapia, microbial load and storage

***Corresponding author:**

E-mail: jowosam@yahoo.com

INTRODUCTION

Fish is becoming increasingly important in the diet of the Nigerian as there is an increase awareness that regular red

meat intake in adult above 40 years of age is not healthy. Fish constitutes 40% of animal protein intake in Nigeria at present (Olatunde, 1989). This is because fish are a cheap source of animal protein with little or no religious rejection of it, which gives it an advantage over pork or beef. Fish are a very perishable commodity, more than cattle, sheep, and poultry, and get spoiled very easily even in temperate climates. So unless it is disposed of quickly after capture, it must be preserved in some way. World fish production was estimated at 100 million tons in 1989, 15% of which was cured in one or another way. One third of the cured fish was smoked and about 20% of the smoked fish goes into international trade. Smoking of fish and/or meat products is one of the most ancient processing technologies. It has been for centuries used for preservation, and is still widely used for this purpose among several communities in the third world where up to 70% of the catch is smoked for preservation (Ward, 1995). Hard curing by salting and smoking permits lengthy preservation by removing moisture, which is essential for bacteriological and enzymatic spoilage. Increasing consumer awareness of the nutritional value of seafood has stimulated a strong demand for seafood and seafood products (Pigott and Tucker, 1990) hence an increase in demand. To satisfy the consumer demand, it is necessary to produce good quality and safe smoked seafood products. Fish and fisheries products are among the most perishable commodities worldwide mainly due to microbial spoilage. About one-third of the world's food production is lost annually as a result of microbial spoilage. In fact, microbial activity is responsible for spoilage of most fresh and of several lightly preserved seafoods (Lund, Baird-Parker and Gould, 2000). Smoked fish and shellfish products can be a source of microbial hazards including *Listeria monocytogenes*, *Salmonella spp.*, and *Clostridium botulinum* (Heintz and Johnson, 1998). Omojowo and Ihuahi (2006) also reported that smoked fish samples from 4 local Markets in Kainji Lake area of Nigeria were dominated by gram-positive bacteria, potential pathogens, coagulase-positive Staphylococcus, and *Escherichia coli*. In addition, human infections may be caused by bacteria endogenous to fish. Bacterial pathogens, which may be transferred from fish to human beings include: *A. hydrophila* (septicemia, diarrhea), *Clostridium botulinum* type E (botulism), *Edwardsiella tarda* (diarrhea), *Plesiomonas shigelloides* (gastroenteritis), *Pseudomonas aeruginosa* (wound infections), *Salmonella sp.* (food poisoning), and *vibrio parahaemolyticus* (food poisoning) (Austin and Austin, 1989). Delay or prevention of microbial spoilage of fish may be achieved by different preservative methods that include the use of smoking and chemical preservatives like Sorbates.

Sorbates are the most effective preservatives against a wide spectrum of food spoilage microorganisms; they include sorbic acid and potassium sorbate. They are among the safest, most efficient and versatile preservatives used in the food industry today. Sorbates are tasteless and odourless. Because they are non-toxic, they are used in a

wide variety of foods, including cheese, yogurt, sour cream, bread, cakes, baking mixes, icing, beverages, margarine, fermented vegetables, fruit products, salad dressing, smoked and salted fish and mayonnaise. The antimicrobial activity of Sorbates against moulds, bacteria etc have been reported (Sofos and Busta 1993) and Sofos, (2000). Considering the antimicrobial activity of Sorbates, this study was carried out to determine the microbial impact of 1-5% concentration of potassium sorbate in smoked tilapia during 8-week storage at room temperature.

MATERIALS AND METHODS

Sample - Treatment

Fresh Tilapia (*Oreochromis niloticus*) was obtained from a private fish pond in National Institute for Freshwater Fisheries Research (NIFFR) Housing Estate, New Bussa, Niger State in November, 2007. The fish samples measuring 12-18cm and weighing 75-90g were transferred within 30 minutes to the laboratory in a sterile polythene bags and then killed by severing the spinal cord with a sterile scalpel and aseptically eviscerated, washed and rinsed in sterile water. The fish samples were randomly chosen and divided into 6 groups of 5 fish each and 5 of the groups were subjected to treatments of 1,2,3,4 and 5% concentration for 5 minutes respectively while the 6th group served as control (untreated samples). A sample from each group was separated from each treatment for microbial analysis. Smoking was done according to the methods described by Omojowo and Ibitoye (2005). After smoking and the fish were allowed to cool down and stored in different boxes. This was done to mimic commercial practices. The samples were drawn after two, four, six and eight weeks of storage; then subjected to analysis.

Microbiological and other Analysis

Total viable count (TVC), Coliform, Staphylococci and Fungi count were evaluated according to the methods described by Harrigan and McCance 1976; Speck 1984 and Sneath, Mair, Sharpe, and Holt, (1986). Moisture contents were estimated as per AOAC (1980). All samples were done in Triplicates. Sensory evaluation was carried out according to the method of Afolabi, Arawomo, and Oke, (1984). Statistical analysis was according to SAS, Institute, Inc, (1992) at P < 0.05.

RESULTS AND DISCUSSION

Microbial Analysis

A study for the absence and presence of the target food borne pathogens such as *Salmonella*, *Staphylococcus*, and *E. coli* is required to evaluate microbial safety of smoked and tilapia. Pathogens can enter the process through raw materials. They can also be introduced into foods during processing from the air, unclean hands, unsanitary utensils and equipment, unsafe water, and sewage, and through cross contamination between raw and cooked product (FDA, 2001). The range of specified microbiological limits recommended by ICMSF (1986) for fish and fishery products is as follows: for the TPC, the maximum recommended

TABLE 1: MICROBIAL LOAD OF TILAPIA TREATED WITH POTASSIUM SORBATE (Log10)

	Microbial group	Control	1%	2%	3%	4%	5%
Day 0 - A	TVC	5.97 ± 0.7 ^a	5.46 ± 1.0 ^b	5.39 ± 0.4 ^b	5.26 ± 0.3 ^c	4.88 ± 0.7 ^d	4.80 ± 0.5 ^d
Day 0 - B	TVC	4.51 ± 0.3 ^a	3.97 ± 0.3 ^b	3.83 ± 0.3 ^c	3.78 ± 0.1 ^c	3.24 ± 0.2 ^d	2.16 ± 0.7 ^e
2 nd wk	TVC	6.16 ± 1.2 ^a	4.25 ± 0.1 ^b	4.27 ± 0.2 ^b	4.25 ± 0.7 ^b	3.90 ± 0.3 ^c	3.00 ± 0.3 ^d
4 th "	TVC	6.75 ± 0.8 ^a	4.95 ± 0.9 ^b	4.77 ± 0.8 ^c	4.80 ± 0.3 ^c	4.77 ± 1.1 ^c	3.86 ± 1.0 ^c
6 th "	TVC	7.37 ± 0.3 ^a	5.55 ± 0.9 ^b	5.48 ± 1.1 ^b	5.49 ± 0.6 ^b	5.32 ± 0.6 ^c	4.10 ± 0.6 ^d
8 th "	TVC	8.91 ± 0.1 ^a	6.87 ± 0.2 ^b	7.01 ± 1.4 ^b	6.24 ± 0.4 ^c	6.03 ± 0.1 ^d	4.32 ± 0.1 ^e
Day 0 - A	Coliform	4.56 ± 0.3 ^a	4.06 ± 0.6 ^b	4.00 ± 1.0 ^b	3.95 ± 0.1 ^{bc}	3.71 ± 0.9 ^{bc}	3.20 ± 0.7 ^c
Day 0 - B	Coliform	3.32 ± 0.9 ^a	1.08 ± 0.3 ^b	1.04 ± 0.3 ^b	1.00 ± 0.8 ^b	0.84 ± 0.3 ^c	0.67 ± 0.2 ^c
2 nd wk	Coliform	3.41 ± 0.1 ^a	1.52 ± 1.1 ^b	1.45 ± 0.5 ^b	1.40 ± 0.5 ^b	1.20 ± 0.4 ^c	0.95 ± 0.3 ^d
4 th "	Coliform	4.06 ± 0.7 ^a	1.97 ± 0.2 ^b	1.83 ± 0.8 ^b	1.71 ± 0.3 ^b	1.64 ± 0.7 ^c	1.30 ± 0.1 ^d
6 th "	Coliform	5.00 ± 1.2 ^a	2.48 ± 0.5 ^b	2.43 ± 1.2 ^b	2.35 ± 0.7 ^{bc}	2.29 ± 0.3 ^c	1.68 ± 0.4 ^d
8 th "	Coliform	5.86 ± 1.0 ^a	2.74 ± 0.9 ^b	2.66 ± 0.4 ^{bc}	2.60 ± 1.1 ^{bc}	2.56 ± 0.5 ^c	2.21 ± 0.2 ^d
Day 0 - A	Staph.	4.51 ± 0.5 ^a	3.81 ± 0.5 ^b	3.80 ± 0.2 ^b	3.77 ± 0.1 ^b	3.21 ± 0.3 ^c	2.90 ± 0.3 ^d
Day 0 - B	Staph.	3.20 ± 0.8 ^a	0.86 ± 0.2 ^b	0.70 ± 0.1 ^b	0.0 ± 0.0 ^c	0.0 ± 0.0 ^c	0.0 ± 0.0 ^c
2 nd wk	Staph.	4.15 ± 1.6 ^a	0.90 ± 0.3 ^b	0.83 ± 0.5 ^b	0.0 ± 0.0 ^c	0.0 ± 0.0 ^c	0.0 ± 0.0 ^c
4 th "	Staph.	4.74 ± 1.1 ^a	1.13 ± 0.1 ^b	1.08 ± 0.3 ^b	0.0 ± 0.0 ^c	0.0 ± 0.0 ^c	0.0 ± 0.0 ^c
6 th "	Staph.	5.10 ± 0.4 ^a	1.60 ± 0.2 ^b	1.41 ± 0.8 ^c	0.0 ± 0.0 ^d	0.0 ± 0.0 ^d	0.0 ± 0.0 ^d
8 th "	Staph.	6.32 ± 0.3 ^a	2.21 ± 0.6 ^b	1.93 ± 0.1 ^c	0.0 ± 0.0 ^d	0.0 ± 0.0 ^d	0.0 ± 0.0 ^d
Day 0 - A	Fungi	4.68 ± 1.2 ^a	4.36 ± 0.2 ^b	4.31 ± 0.7 ^b	3.78 ± 0.6 ^c	3.24 ± 0.4 ^d	3.02 ± 0.6 ^e
Day 0 - B	Fungi	3.34 ± 0.1 ^a	1.18 ± 0.1 ^b	1.10 ± 0.5 ^b	1.00 ± 0.3 ^b	0.41 ± 0.1 ^c	0.0 ± 0.0 ^d
2 nd wk	Fungi	4.64 ± 0.7 ^a	1.68 ± 0.3 ^b	1.54 ± 0.5 ^b	1.21 ± 0.5 ^c	0.62 ± 0.2 ^d	0.0 ± 0.0 ^e
4 th "	Fungi	5.20 ± 0.1 ^a	2.32 ± 0.9 ^b	2.26 ± 0.3 ^b	1.64 ± 0.7 ^c	0.78 ± 0.3 ^d	0.0 ± 0.0 ^e
6 th "	Fungi	5.58 ± 0.8 ^a	3.01 ± 0.5 ^b	2.88 ± 0.8 ^b	2.82 ± 0.7 ^b	1.0 ± 0.4 ^c	0.0 ± 0.0 ^d
8 th "	Fungi	7.52 ± 0.3 ^a	3.70 ± 1.4 ^b	3.53 ± 0.5 ^c	2.45 ± 0.3 ^c	1.52 ± 0.7 ^d	0.30 ± 0.1 ^e

Mean ± standard deviation of triplicate experiments and 2 replicates of each sample (6 readings of each sample) Using superscript a, b, c, d, e, f, means in the same rows with different superscript are significantly different (p < 0.05).

KEY:

A = before smoking

B = after smoking

TABLE 2. ORGANOLEPTIC ATTRIBUTES OF FRESHLY SMOKED AND 8TH WEEK STORED TILAPIA TREATED WITH POTASSIUM SORBATE

	Taste	Flavour	Texture	Appearance	Overall-acceptability
CONTROL	4.2	4.1	4.2	4.1	4.1
FRESHLY SMOKED - 1 %	4.7	4.6	4.6	4.8	4.8
2 %	4.5	4.3	4.3	4.9	4.7
3 %	3.8	3.6	3.3	3.3	4.1
4 %	3.3	3.5	3.0	2.9	3.0
5 %	2.8	2.1	2.9	3.4	2.5
CONTROL (8TH WK)	3.3	3.5	3.6	3.6	3.0
8TH WEEK OLD - 1%	4.0	4.2	4.1	4.3	4.3
2%	4.2	4.2	4.3	4.1	4.3
3%	4.0	3.8	3.8	4.1	4.0
4%	3.1	2.9	3.0	3.7	3.2
5%	2.8	2.9	2.9	4.1	3.2

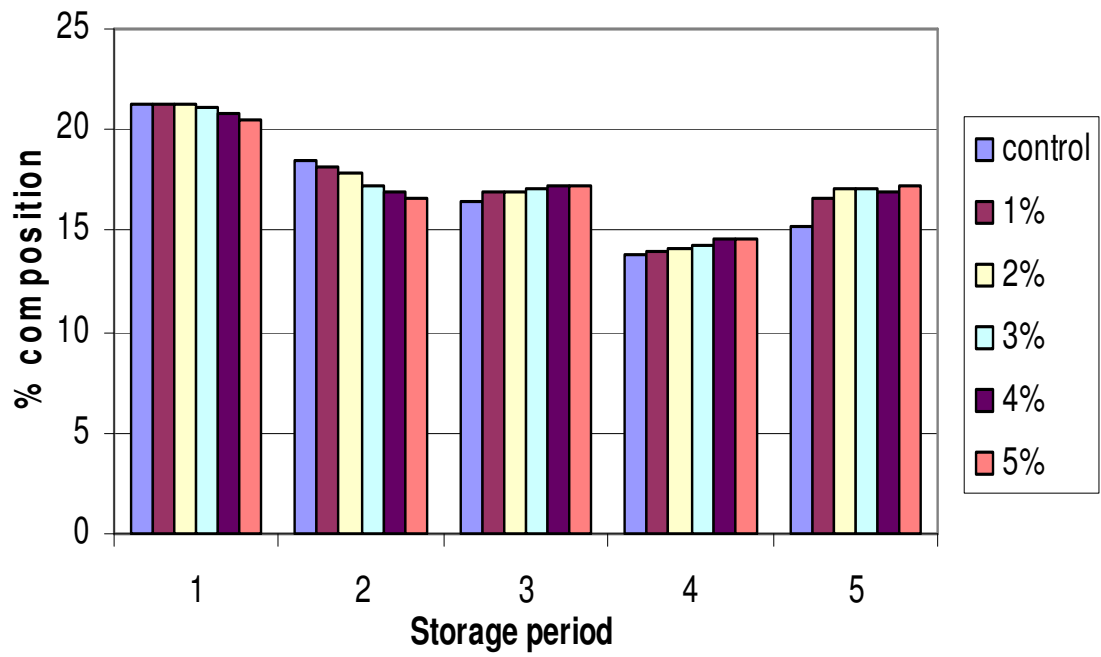


Fig. 1. Moisture contents of Smoked Tilapia Preserved with Potassium sorbate

Key
 1= Day 0
 2= 2nd Wk
 3 = 4th Wk
 4= 6th Wk
 5= 8th Wk

bacterial counts for good quality products (m) is 5×10^5 (5.7 log₁₀ CFU/g) and the maximum recommended bacterial counts for marginally acceptable quality products (M) is 10^7 (7 log₁₀ CFU/g). For *E. coli*, the m value is 11 (1.0 log₁₀ CFU/g) and the M value is 500 (2.7 log₁₀ CFU/g), and for *Staphylococcus*, m value is 10^3 (3 log₁₀ CFU/g) (ICMSF, 1986).

Total Viable count (TVC), Coliform, Staphylococci and Fungi count in log CFU/g of fresh and smoked tilapia samples plated on selective and non-selective media are shown in Tables 1. TVC of the fresh non-treated (control) tilapia was 5.97 log CFU/g but after the sample were subjected to treatments with potassium sorbate the reduction was highest in 5% (4.80 log CFU/g and least in 1% (5.46 log CFU/g as shown in Table 1). Similarly, coliform was reduced from 4.56 log CFU/g in the control to 3.20 log CFU/g in 5% and least in the treatments was 4.06 log CFU/g of 1% concentration. In the same vein, staphylococci count was reduced from 4.51 log CFU/g in the control to 2.90 log CFU/g, in 5% and least in the treatments was 1% (3.81 log CFU/g) in treated sample. Fungi count reduced from 4.68 log CFU/g (control) to 3.02 log CFU/g in 5% conc. and least in 1% (4.36 log CFU/g).

Smoking sharply reduced the total viable count in all samples but the sample treated with 5% potassium sorbate showed the greatest reduction and maintained a low level throughout 8 weeks of storage, especially on day 0 with 2.16 log CFU/g. The TVC of smoked control (untreated) samples was the highest throughout the period of storage reaching 8.91 log CFU/g on the 8th week. The results obtained were similar to those reported by Efiuvwevwere and Ajiboye (1996), where the samples treated with 0.4% potassium sorbate showed the lowest microbial load and maximum shelf stability. Similar to TVC, the coliform count of the smoked samples treated with 5% potassium sorbate had the highest reduction to 0.67 log CFU/g on day 0 and remain the lowest of the treatments throughout the period of storage. Significant increases in coliform population of all samples occurred after 4 weeks of storage. However, Coliform count of all treated samples was less than 3.0 log CFU/g throughout the 8-week storage. In the control samples, the Coliform population showed 5.86 log CFU/g on the 8th week. The high coliform count recorded in this report may be due to contamination from the animal manure used in fertilizing the ponds at one time or the other. In the staphylococcus population, the smoked sample treated with 3-5% potassium sorbate reduced the staphylococcus count to 0 and remained 0 until the end of 8th week storage (Table 1.) The isolation of *Staphylococcus* in smoked samples on day 0 may be attributed to post processing contamination. However, *Staphylococcus* was killed by the treatments 3-5% potassium sorbate. The population of the fungi reduced in all the treatments and at the end of the 8-week storage time; however, the sample treated with 5% potassium sorbate showed 0 counts till the 4th week with very few count at the end of the storage. These results were also similar to that reported by Virginia, (2002) where the coliform,

staphylococcus and fungi count in the control sample of blue catfish was the highest compared to other treated sample. Actually, the control sample was completely covered by mold on the 6th week.

It is of interest to observe that in spite of the slightly reduced moisture contents (from 2nd to 6th week) in almost all the samples, microbial load still increases dramatically. This suggests that one single factor may not account for these microbial changes. Cross contamination, pH, purity of preservatives is among other factors that can influence microbial changes. The bacterial contamination of hot smoked fish just out of the smokehouse is usually below 10^3 per gram (Doe, 1998). The TVC of the treated samples were all about 5×10^5 CFU/g to the 6th week which belong to m in a three-class attribute plan and signifies good quality. Low levels of coliform bacteria were detected and the pathogens *Staphylococcus aureus* counts were below 10^3 in all the treated samples till the 8th week. The control however, has TVC higher than 5×10^5 CFU/g in the second week and higher than the recommended limit 7.0 log CFU/g (ICMSF, 1986) after the 4th week. In addition the coliform count already exceeded 10^3 even immediately after smoking. This finding is of concern as a result of the associated public health implications. For example, generally, hot smoked fish are consumed in the tropics with little or no further processing/cooking; thus, they fall into the high-risk category of foods (ICMSF, 1986). Hence there is a need for the use of appropriate percentage of choice antimicrobial agent.

BACTERIAL ISOLATES

All treated smoked sample were negative for *E. coli* and *Streptococcus sp.* The control and the fresh fish treated samples showed the following bacteria flora *Bacillus coagulans*, *B. cereus*, *Klebsiella ozanae*, *Proteus vulgaris*, *Escherichia coli*, and *Staphylococcus aureus*, while the fungi isolated include, *Aspergillus niger*, *A. candidus*, *A. flavus* and *A. nidulan* while the smoked untreated dominated by the following organisms *B. coagulans*, (about 70% of the isolates) while the remaining being *S. aureus*, and *Streptococcus sp.* The treated sample showed the microbial load in the following pattern; 1% and 2% potassium sorbate of the fish samples contains the following spp *B. coagulans*, *S. aureus*, *K. ozanae*, *A. candidus* and *A. nidulan* while in 3% and 4% potassium sorbate treated samples have the following isolates *B. coagulans*, *K. ozanae* and *A. nidulan* while 5% treatment have only *B. coagulans*.

Proximate Analysis

Moisture contents were within 74% - 77.0% before and after treatment prior to smoking. 79.4% for fresh tilapia and catfish respectively. Moisture content decreased sharply after the smoking to 20.55 - 21.35. The moisture content continues to decrease till the 4th week before increasing again (Fig.1.). This decrease was due to loss of water during smoking (Asiedu *et al.*, 1991). The moisture content of all treatments remained similar throughout 8 weeks of storage.

Organoleptic Assessment

The quality of the smoked fish (both treated and untreated) was evaluated immediately after smoking and after storage for 8th week on taste, flavour, texture, appearance and overall acceptability using 5- hedonic scale of { 5= like much, 4 = like, 3 = neither like nor dislike, 2 = dislike, 1= dislike much.. The fish flesh overall score was given to both untreated (control) and the one of various treatment using a hedonic scale of 1- 5 fish scoring less than 2 being regarded as unacceptable. This assessment was done for both tilapia and the catfish.

Table 2 summarizes the taste panel results. From the result, the trend of scores for the overall acceptability of freshly smoked tilapia is as follows 1% > 2% > 3% = C > 4% > 5% while on the 8th week the trend is 2% = 1% > 3% > 4 % > 5 % From this study therefore, tilapia treated with 1%, 2% and 3% potassium sorbate, smoked and stored for 8 weeks are well accepted by the consumers since they fall into the LIKE group and above.

CONCLUSION

This study has reveals that the samples treated with 5% potassium sorbate before smoking showed the greatest reduction and maintained a low level throughout the 8th weeks of storage. However, organoleptic study has reveals that the samples treated with 1-3% potassium sorbate are well preferred by the consumers since it fall in the group of LIKE and above. Hence, 1-3% potassium sorbate can be used as a choice preservative in smoked catfish without adversely affecting quality in terms of lipid oxidation, color, microbial and nutritional quality. However, for better output 3% potassium sorbate as a choice antimicrobial agent is hereby recommended since it has been found to keep smoked fish in wholesome state for 8th week, reducing the TVC to 6.24 log CFU/g, the coliform to 2.60log CFU/g, staphylococcus count to 0.0s and fungi to 2.45 log CFU/g at the end of 8th week storage. This will ensure prolonged shelf life and safe consumption of smoked fish of ICMSF standard of smoked fish quality.

ACKNOWLEDGMENTS

The authors are grateful to the Executive director of NIFFR (Dr Aminu Raji) for financing this research work.

REFERENCES

Afolabi, O.A., Arawomo, O.A. and Oke, L.O., 1984. Quality changes of Nigerian traditionally processed freshwater fish species. I. Nutritive and organoleptic changes. *Journal of Food Technology* 19, 333-340.

AOAC 1980. Official methods of analysis of the AOAC (W. Hortwitz E.d.), 13th ed. AOAC, Washington D.C., U.S.A. 858pp.

Asiedu, M., Julsham, k., and Lie, O., 1991. Effect of local processing methods on three fish species

from Ghana: Part I, Proximate composition, fatty acids, minerals, trace elements, and vitamins. *Food Chem.* 40: 309-321.

Austin, B. and Austin, D., 1989. General Introduction. *In Methods for the Microbiological Examination of fish and Shellfish*, B. Austin and D.A. Austin (Ed.) Ellis Horwood Limited, England, p19-24.

Doe P.E., 1998. Fish drying and smoking Production and Quality. *Technomic Publishing Co., Inc.* Lancaster, Pennsylvania.

Efivuvwevwere, B.J. and Ajiboye, M.O., 1996. Control of Microbiological quality and shelf-life of catfish (*Clarias gariepinus*) by chemical preservative and smoking. *Journal of Applied Bacteriology* 80, 465-470.

FDA, Department of Health and Human Services, 2001. FDA & EPA Safety levels in regulations and Guidance. *In Fish and fisheries Products, Hazards & controls guidance: Third Ed.* Appendix 5, p. 285.

Harrigan, W.F. and McCance, M.F. 1976. Laboratory Methods in Food and Dairy Microbiology, 2nd Edn. London: Academic Press.

Heintz, M.L., and Johnson, J.M. (1998). The Incidence of *Listeria* spp., *Salmonella* spp., and *Clostridium botulinum* in smoked fish and shellfish. *Journal of Food Protection*, 61 (3): 318-323.

ICMSF (International Commission on Microbiological Specifications for Foods), 1986 Microorganism in Foods 2, Sampling for Microbiological Analysis. Principles and Specific Applications, 2nd edn. Oxford: Blackwell Science.

Lund, B.M., Baird-Parker, A.C. and Gould G.W., 2000. *The Microbiological Safety and Quality of Foods*. Aspen Publishers, Inc. Gaithersburg, Maryland, USA, 1885.

Olatunde, A.A., 1989. Focusing on research approaches to the study of fishery biology in Nigeria inland waters. *In proceedings of the conference on two Decade of Research on Kainji*. NIFFR, New Bussa, 29th Nov-1st Dec. 1989, 538-541

Omojowo F.S. and Ibitoye A., 2005. Comparisons of the Microbial qualities of smoked *Clarias gariepinus* using four different kilns. *In Fison proceeding, Port Harcourt* 14th-18th Nov. 2005.

Omojowo F.S. and Ihuahi J.A., 2006. Microbiological Quality and Safety of smoked fish from

Kainji Lake area. *In African Scientist*, Vol. 7, No. 4, 177-181.

Pigott G. and Tuckker. B., 1990. Seafood Effects of Technology on Nutrition, Marcel Dekker Inc. N.Y. p 155-170.

Ward, A.R. 1995. Fish smoking in the tropics. A review. *Trop. Sci.* 35, 103 – 112.

SAS Institute, Inc. 1992. SAS User's Guide: Statistics. SAS Institute Inc., Cary, NC.

Sofos, J.N. and Busta, F.F., 1993. Sorbic acid and sorbates. *In Antimicrobial in Food*, ed. P.M. Davidson and A.L., pp. 49-94. New York: Marcel Dekker, Inc.

Sofos, J.N., 2000. Sorbic acid. *In Natural Food Antimicrobial Systems*, ed. A.S. Naidu, pp.637-659. Boca Raton, FL: CRC Press.

Sneath, P.H., Mair, N.S., Sharpe, M.E. and Holt, J.G., 1986. *Bergey's Manual of Systemic Bacteriology*, Vol. 2. Baltimore: Williams and Wilkins.

Speck, M.L., 1984. *Compendium of Methods for the Microbiological Examination s of Foods*, 2nd edn. Washington, D.C: American Public Health Association.

Ufodike, E.B.C. Obureke, J.U. 1989. Effects of preservation techniques on quality of *Oreochromis niloticus* muscle. *J. Aqua. Sci.* 4: 1-5.

Virginia L.T.A, 2002. Hazard Analysis and Critical Control Point (HACCP), Microbial safety and Shelf life of Smoked Blue catfish (*Ictalurus furcatus*). M.sc Thesis submitted to the Graduate Faculty of the Louisiana State University.